

CLAIMS

[0051] What is claimed as new and desired to be protected by Letters Patent of the United States is:

1. A magnetic memory element comprising:
a first and second ferromagnetic layer one of said layers being a pinned layer and the other being a free layer;
a first nonmagnetic layer formed between said first and said second ferromagnetic layers, said first nonmagnetic layer having an opening therein to a surface of at least one of said first and second ferromagnetic layers; and
a nonmagnetic tunnel barrier layer formed within said opening, said first nonmagnetic layer being thicker than said tunnel barrier layer.
2. The element of claim 1 wherein a said tunnel barrier layer has a smaller surface area than at least one of said first and said second ferromagnetic layers.
3. The element of claim 1 wherein said tunnel barrier layer has a smaller surface area than each of said first and second ferromagnetic layers.
4. The element of claim 1 wherein said tunnel barrier layer comprises aluminum oxide.
5. The element of claim 3 wherein said first nonmagnetic layer comprises aluminum oxide.

6. The element of claim 4 wherein said first nonmagnetic layer has a thickness in a range of about 20 Angstroms to about 300 Angstroms.
7. The element of claim 5 wherein said tunnel barrier layer has a thickness in a range of about 5 Angstroms to about 20 Angstroms.
8. The element of claim 1 wherein said tunnel barrier layer is centered with respect to said free ferromagnetic layer.
9. The element of claim 1 wherein said tunnel barrier layer is positioned off-center with respect to said free ferromagnetic layer.
10. The element of claim 1 wherein said tunnel barrier layer has a different shape than said free ferromagnetic layer.
11. The element of claim 1 wherein said tunnel barrier layer and said first ferromagnetic layer have substantially the same shape.
12. The element of claim 1 wherein said tunnel barrier layer is formed of a material layer which extends outside of said opening.
13. A magnetic memory device comprising:
at least one magnetic random access memory element, said magnetic random access memory element comprising a first ferromagnetic layer formed over a first line conductor; a nonmagnetic layer formed over said first ferromagnetic layer, said nonmagnetic layer containing an opening to a surface of said first ferromagnetic layer; a tunnel barrier layer formed at least within said opening and in contact with said first ferromagnetic layer; and a second ferromagnetic layer formed over at least said tunnel barrier layer, one of said first

and second ferromagnetic layers being a pinned layer and the other of said first and second ferromagnetic layers being a sense layer.

14. The device of claim 13 whereby said nonmagnetic layer is thicker than said tunnel barrier layer.

15. The device of claim 13 wherein said tunnel barrier layer comprises aluminum oxide.

16. The device of claim 15 wherein said nonmagnetic layer comprises aluminum oxide.

17. The device of claim 14 wherein said nonmagnetic layer has a thickness in a range of about 20 Angstroms to about 300 Angstroms.

18. The device of claim 17 wherein said tunnel barrier layer has a thickness in a range of about 5 Angstroms to about 20 Angstroms.

19. The device of claim 13 wherein said free ferromagnetic layer has a larger surface area than said tunnel barrier layer.

20. The device of claim 13 wherein said tunnel barrier layer is centered with respect to said free ferromagnetic layer.

21. The device of claim 13 wherein said tunnel barrier layer is positioned off-center with respect to said free ferromagnetic layer.

22. The device of claim 13 wherein said tunnel barrier layer is of a different shape than said free magnetic orientation ferromagnetic layer.

23. The device of claim 13 wherein said tunnel barrier layer and said free ferromagnetic layer are of substantially the same shape.

24. The device of claim 13 further wherein said tunnel barrier layer is part of a material layer which extends outside of said opening.

25. A magnetic memory device comprising:
a plurality of memory elements, each of said memory elements comprising a pinned ferromagnetic layer, a free ferromagnetic layer, and at least two nonmagnetic layers between said pinned ferromagnetic layer and said free ferromagnetic layer, whereby one of said nonmagnetic layers is thicker than the other of said nonmagnetic layers further whereby said thicker non magnetic layer contains an opening to at least one of said pinned ferromagnetic layer and said free ferromagnetic layer, said opening having a portion of said thinner nonmagnetic layer disposed therein.

26. The device of claim 25 wherein said portion of said thinner nonmagnetic layer forms a tunnel barrier layer.

27. The device of claim 26 wherein said tunnel barrier layer has a smaller surface area than said free ferromagnetic layer.

28. The device of claim 26 wherein said tunnel barrier layer has a smaller surface area than said pinned ferromagnetic layer.

29. The device of claim 25 wherein at least one of said nonmagnetic layers comprises aluminum oxide.

30. The device of claim 26 wherein said tunnel barrier layer comprises aluminum oxide.

31. The device of claim 25 wherein said thicker nonmagnetic layer has a thickness in a range of about 20 Angstroms to about 300 Angstroms.

32. The device of claim 31 wherein said thinner nonmagnetic layer has a thickness in a range of about 5 Angstroms to about 20 Angstroms.

33. The device of claim 32 wherein said tunnel barrier layer has a thickness in a range of about 5 Angstroms to about 20 Angstroms.

34. The device of claim 25 wherein said free ferromagnetic layer has edges formed over at least said thicker nonmagnetic layer.

35. The device of claim 26 wherein said tunnel barrier layer is centered with respect to said free ferromagnetic layer.

36. The device of claim 26 wherein said tunnel barrier layer is positioned off-center with respect to said free ferromagnetic layer.

37. The device of claim 26 wherein said tunnel barrier layer is of a different shape than said free ferromagnetic layer.

38. The device of claim 26 wherein said tunnel barrier layer and said free ferromagnetic layer have substantially the same shape.

39. A processor-based system comprising:
a processor;
a memory circuit coupled to said processor, said memory circuit including a plurality of magnetic random access memory elements, each of said memory elements comprising: a first ferromagnetic layer formed over a first line conductor, a second ferromagnetic layer formed over said first ferromagnetic

layer, and first and second nonmagnetic layers between said first and second ferromagnetic layers whereby said first nonmagnetic layer is thicker than the other of said nonmagnetic layers, said thicker nonmagnetic layer containing an opening to at least one of said first and second nonmagnetic layers, said opening having a portion of said thinner nonmagnetic layer disposed therein.

40. The system of claim 39 wherein said portion of said thinner nonmagnetic layer forms a tunnel barrier layer.

41. The system of claim 40 wherein said tunnel barrier layer has a smaller surface area than either of said first and said second ferromagnetic layers.

42. The system of claim 40 wherein said tunnel barrier layer has a smaller surface area than each of said first and said second ferromagnetic layers.

43. The system of claim 40 wherein one of said first and second ferromagnetic layers has a pinned magnetic orientation.

44. The system of claim 43 wherein another of said first and second ferromagnetic layers has a free magnetic orientation.

45. The system of claim 39 wherein said first and said second nonmagnetic layers comprise aluminum oxide.

46. The system of claim 40 wherein said tunnel barrier layer comprises aluminum oxide.

47. The system of claim 39 wherein said first nonmagnetic layer has a thickness in a range of about 20 Angstroms to about 300 Angstroms.

48. The system of claim 47 wherein said second nonmagnetic layer has a thickness in a range of about 5 Angstroms to about 20 Angstroms.

49. The system of claim 46 wherein said tunnel barrier layer has a thickness in a range of about 5 Angstroms to about 20 Angstroms.

50. The system of claim 44 wherein said free ferromagnetic layer has a larger surface area than said tunnel barrier layer.

51. The system of claim 39 wherein said free ferromagnetic layer has edges formed over at least said thicker nonmagnetic layer.

52. The system of claim 40 wherein said tunnel barrier layer is centered with respect to said free ferromagnetic layer.

53. The system of claim 40 wherein said tunnel barrier layer is positioned off-center from said free ferromagnetic layer.

54. The system of claim 40 wherein said tunnel barrier layer is of a different shape than said free ferromagnetic layer.

55. The system of claim 40 wherein said tunnel barrier layer and said free magnetic orientation ferromagnetic layer are of substantially the same shape.

56. The system of claim 39 further wherein said thinner nonmagnetic layer is a tunnel barrier layer.

57. A method of forming a magnetic tunnel junction, said method comprising the steps of:

forming a first magnetic layer;

forming a first nonmagnetic layer in contact with said first magnetic layer;

removing a portion of said first nonmagnetic layer to form an opening which exposes a portion of said first magnetic layer; and
forming a tunnel barrier layer within said opening in contact with said first magnetic layer; and
forming a second magnetic layer over said tunnel barrier layer.

58. The method of claim 57 wherein said first nonmagnetic layer is formed to be thicker than said tunnel barrier layer.

59. The method of claim 58 wherein one of said first and second magnetic layers is a free layer.

60. The method of claim 59 wherein the other of said first and second magnetic layers is a pinned layer.

61. The method of claim 60 wherein said tunnel barrier layer is formed to have a smaller surface area than said free layer.

62. The method of claim 57 wherein said first nonmagnetic layer comprises aluminum oxide.

63. The method of claim 57 wherein said tunnel barrier layer comprises aluminum oxide.

64. The method of claim 58 wherein said first nonmagnetic layer is formed to have a thickness in a range of about 20 Angstroms to about 300 Angstroms.

65. The method of claim 64 wherein said tunnel barrier layer is formed to have a thickness in a range of about 5 Angstroms to about 20 Angstroms.

66. The method of claim 60 wherein edges of said free layer are formed over at least said first nonmagnetic layer.
67. The method of claim 60 wherein said tunnel barrier layer is formed to have a smaller surface area than said free layer.
68. The method of claim 60 wherein said tunnel barrier layer is centered with respect to said free layer.
69. The method of claim 60 wherein said tunnel barrier layer is positioned off-center with respect to said free layer.
70. The method of claim 60 wherein said tunnel barrier layer is formed to have a different shape than said free layer.
71. The method of claim 60 wherein said tunnel barrier layer and said free layer are formed to have substantially the same shape.
72. The method of claim 60 further wherein said tunnel barrier layer is formed to extend outside of said opening.
73. A method of forming a magnetic random access memory element, said method comprising:
- forming a substrate;
 - forming at least one first conductive line;
 - forming at least one first ferromagnetic layer in electrical communication with said at least one first conductive line;
 - forming at least one first nonmagnetic layer over said at least one first ferromagnetic layer;

forming at least one opening in said at least one first nonmagnetic layer;
forming a tunnel barrier layer within said opening;
forming at least one second ferromagnetic layer over said tunnel barrier layer; and
forming at least one second conductive line in electrical communication with said at least one second ferromagnetic layer.

74. The method of claim 73 where one of said at least one first and said at least one second ferromagnetic layers is a free ferromagnetic layer.

75. The method of claim 74 wherein the other of said at least one first and said at least one second ferromagnetic layers is a pinned ferromagnetic layer.

76. The method of claim 73 wherein said at least one first nonmagnetic layer is thicker than said tunnel barrier layer.

77. The method of claim 75 wherein said tunnel barrier layer is formed to have a smaller surface area than said free ferromagnetic layer.

78. The method of claim 73 wherein said at least one first nonmagnetic layer comprises aluminum oxide.

79. The method of claim 73 wherein said tunnel barrier layer comprises aluminum oxide.

80. The method of claim 73 wherein said first nonmagnetic layer is formed to have a thickness in a range of about 20 Angstroms to about 300 Angstroms.

81. The method of claim 80 wherein said tunnel barrier layer is formed to have a thickness in a range of about 5 Angstroms to about 20 Angstroms.

82. A magnetic memory element comprising:
a first and second plurality of layers wherein one of said first and said second plurality of layers is a pinning structure and the other of said first and said second plurality of layers is a sensing structure; whereby said sensing structure comprises at least one free ferromagnetic layer and said pinning structure comprises at least one pinned ferromagnetic layer;

a first nonmagnetic layer formed between said pinning structure and said sensing structure, said first nonmagnetic layer having an opening therein to a surface of at least one of said ferromagnetic layers of at least one of said pinning structure and said sensing structure;

a nonmagnetic tunnel barrier layer formed within said opening, said first nonmagnetic layer being thicker than said tunnel barrier layer.

83. The element of claim 82 wherein said pinning structure comprises a layer comprising tantalum.

84. The element of claim 82 wherein said pinning structure comprises a seed layer.

85. The element of claim 84 wherein said seed layer comprises nickel-iron.

86. The element of claim 82 wherein said pinning structure comprises an anti-ferromagnetic layer.

87. The element of claim 86 wherein said antiferromagnetic layer comprises manganese-iron.

88. The element of claim 82 wherein said pinned ferromagnetic layer comprises nickel-iron.

89. The element of claim 82 wherein said sensing structure comprises a cap layer.

90. The element of claim 89 wherein said cap layer comprises tantalum.

91. The element of claim 82 wherein said free ferromagnetic layer comprises nickel-iron.

92. A method of forming a magnetic tunnel junction, said method comprising the steps of:

forming a pinning structure comprising a pinned layer;
forming a first nonmagnetic layer in contact with said pinning structure;
removing a portion of said first nonmagnetic layer to form an opening which exposes a portion of said pinning structure; and

forming a tunnel barrier layer within said opening in contact with said pinning structure; and

forming a sensing structure comprising a free layer over said tunnel barrier layer.

93. The method of claim 92 wherein said pinning structure is formed to be thicker than said tunnel barrier layer.

94. The method of claim 92 wherein said step of forming said pinning structure further comprises forming a seed layer.

95. The method of claim 94 wherein said seed layer comprises nickel-iron.

96. The method of claim 92 wherein said step of forming said pinning structure further comprises forming an anti-ferromagnetic layer.

97. The method of claim 96 wherein said antiferromagnetic layer comprises manganese-iron.

98. The method of claim 92 wherein said tunnel barrier layer is formed to have a smaller surface area than said sensing structure.

99. The method of claim 92 wherein said pinned ferromagnetic layer comprises nickel-iron.

100. The method of claim 92 wherein said step of forming said sensing structure further comprises forming a cap layer.

101. The method of claim 100 wherein said cap layer comprises tantalum.

102. The method of claim 92 wherein said free ferromagnetic layer comprises nickel-iron.